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(56) Documents Cited  
GB 2348465 A GB 2307722 A GB 2279412 A  
GB 2039624 A JP 110044288 A JP 030189372 A

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(54) Abstract Title  
**Marine power station**

(57) A marine power station comprises a single vertically-oriented bottle-shaped tower 1 and incorporates a water turbine 2 housed in a tunnel 3 close to its gravity base 4 and a darrieus wind turbine aero-generator 7 mounted on a platform 8 on a tubular mast 10. The water turbine is protected by meshes 17 and 18 and rotatable shutter doors (20 Fig 2) and (21) mounted on a ring frame (19). The power station is installed as one structure by tug assisted float-out or in sections by crane barge at a near-shore site following construction at a nearby onshore base and is settled by water jet 6 soil liquifaction. Multi-plex two-way signal conductors in the core of the power cable enable remote monitoring and control.

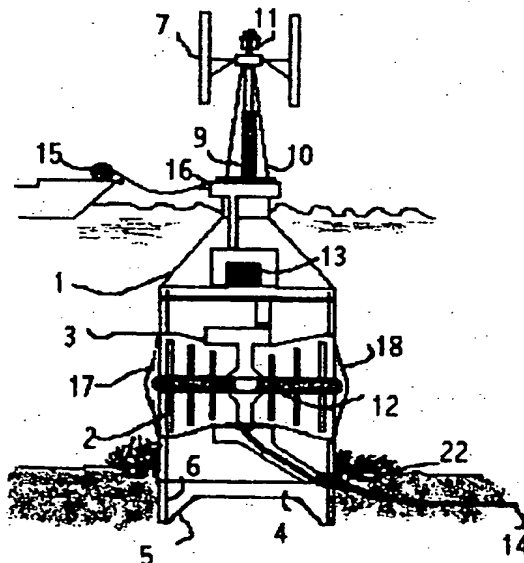


FIGURE 1

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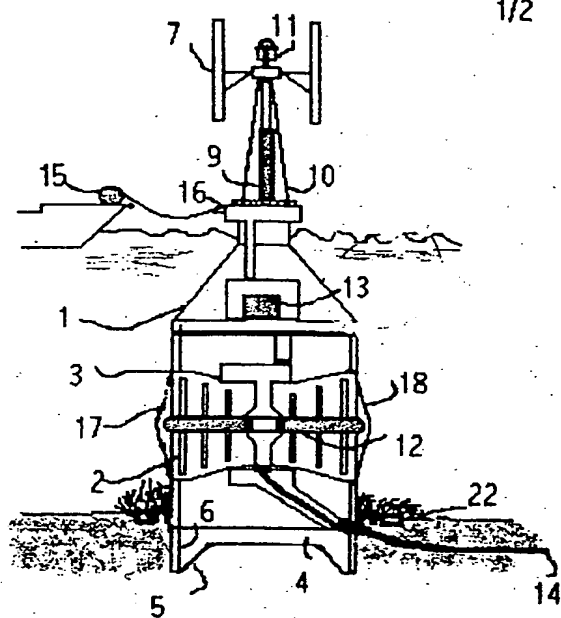


FIGURE 1

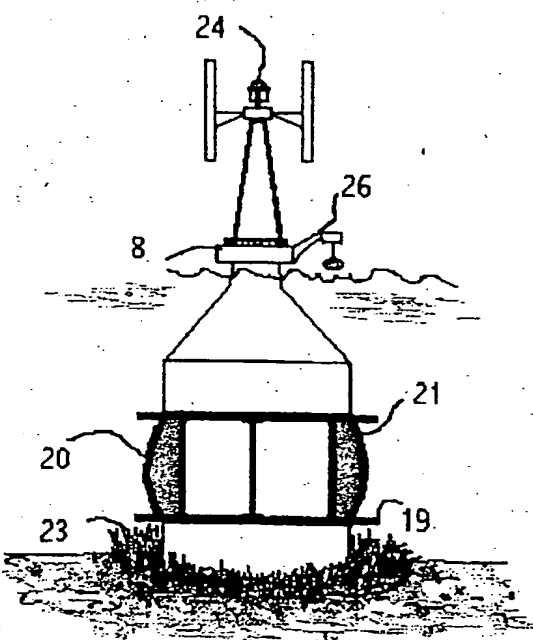


FIGURE 2

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FIGURE 3

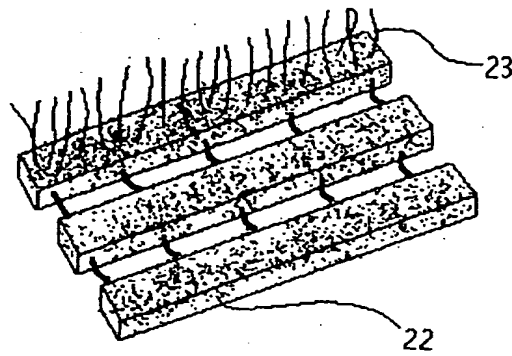
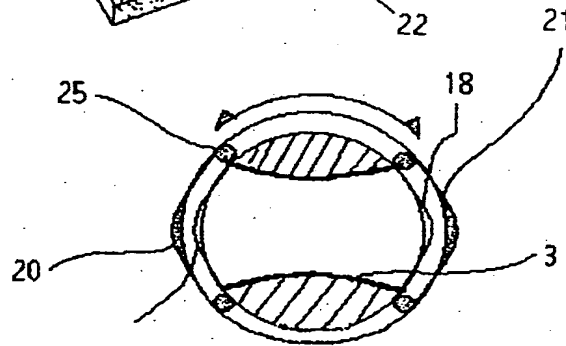


FIGURE 4



## Marine Power Station

The present invention provides a marine-based power station conceived as a single structure which incorporates a water turbine driven by tidal current and an aero-generator mounted on a mast above the water.

Electrical generators using the medium of the power of the wind or water have been proposed and some concepts have been constructed in various forms both historically and in recent times. All of the devices so far described have utilised only one of these two media directly as a natural power source in their structure. The capital cost of the structure has always dominated the unit of cost of power generated as the 'fuel' is of course entirely free.

The fixed relationship between power generated and structural cost has always been an obstacle to providing competitively priced electrical power from a source of sustainable natural energy, even with Governmental subsidies and penalties on fossil-fuel generators. Offshore constructions attract high costs by the nature of the environment. Land-based generators have limitations of average maximum output and inherent variability in terms of instantaneous power levels and durations. In addition, siting is constrained by the widespread perceived visual pollution which can impact the selection of the optimum sites.

By maximising the power generating capacity and at the same time minimising the installed cost of the structure, a viable unit cost of generated power may be achieved.

It is the objective of the present invention to deliver a marine power station operated by pollution-free sustainable energy at an economically viable capital cost and without creating any visual amenity criticisms.

The preferred economic construction method is reinforced or pre-stressed concrete although a fabrication of steel tubulars will perform the same function, but at a higher capital cost.

The structure is to be sited at a selected near-shore location possessing a high velocity tidal current regime coupled with a high average annual wind speed/duration profile. Such a location would not attract the adverse comments with which proposals for land-based schemes often have to compete. Design life is 25 years in common with standard offshore engineering practice but as the power output will not suffer from gradual source depletion or equipment obsolescence, the economic model predicts an acceptable return on investment.

The permanent orientation of the structure when installed on seabed is such that the turbine tunnel captures the maximum effect of both tidal stream runs in either direction (ie. both diurnal tides). The cross-section of the turbine tunnel is configured to accommodate the turbine design. This cross-section area may be constant or varied to create a venturi effect to optimise the selected turbine blade characteristics. The turbine is protected in operation by steel mesh covers at each entrance which are shaped to deflect large objects and only allow small debris to pass through. There are several methods which may be used to exclude

the tidal flow through the turbine whilst it is stopped for maintenance or repair. They are all essentially performing the function of a valve.

The aero-generator located on the topsides access platform may be a horizontal or vertical axis device whichever is more appropriate to the wind directional characteristics of any particular selected location. A vertical axis machine does not require the expensive yawing mechanism and electrical brush-gear pickups which are necessary for the effective operation of a horizontal axis machine. The vertical axis device is however not self-starting and needs to be provided with some form of start-up device. Its efficiency is somewhat less than that of the horizontal machine.

Construction is onshore and preferably local to the chosen site. A minimal offshore installation programme is achieved by a tug-assisted float-out of the whole structure and then flooding at site to sink into final position. Alternatively, a barge transports structural segments which are then coupled together at the site using a crane lift. An electrical cable is laid and buried to deliver the output to an onshore terminal for distribution to either a local consumer or as input to the National Grid. The power station is normally unmanned and operates autonomously monitored and controlled remotely by multiplex signal elements incorporated in the core of the power cable. Provision for occasionally accessing and maintaining the systems by shore-based personnel includes a docking scheme for light watercraft, short-term accommodation/facilities and a basic workshop for routine repair and maintenance duties.

A preferred embodiment of the invention will now be described by way of example with reference to the accompanying drawings, Figures 1-4 which are listed below.

Figure 1. Is a general arrangement of the power station in part cross-section and depicts its main functional elements and general form of construction.

Figure 2. Is a general arrangement of the power station with the water turbine inoperative. The shutter doors have been rotated to the closed position to exclude the tidal current when it is necessary or required to stall the turbine for maintenance or repair.

Figure 3. Is a typical concrete mat assembly used in the offshore industry to prevent the removal of material by scour at the base of marine structures.

Figure 4. Is a plan view of the rotating shutter doors.

Referring to the drawing in figures 1 to 4, the structure comprises a variable diameter circular cross-section main tower having a bottle-shaped configuration 1. It incorporates a horizontal water turbine 2, rotating in a tunnel 3, a self-founding gravity base 4, with an integral shear keying 5 and high pressure water jets 6. The tunnel through the

tower achieves structural characteristics and benefits of a arch and also minimises the use of materials. An aéro-generator 7, is supported on a topsides access platform 8. In this example, a vertical axis Darrieus-type wind machine drives a slimline electrical alternator 9, encased within the tubular mast 10. This aéro-generator example also includes a Savonius-type device 11, to provide self-starting to the main machine.

The subsea water turbine drives a sealed slimline electrical alternator 12, as the tidal current flows through the turbine tunnel 3.

All control, monitoring and distribution systems for both the subsea water turbine 2 and the topsides aéro-generator 7 are contained within the main tower 1 and located immediately beneath the access platform 8 at a control centre 13.

An electrical cable 14, laid and buried between the marine power station and an onshore terminal carries power and two-way telemetry signals.

The tower is constructed at a temporary onshore base close to the final installation site. Depending on size, location and local facilities available, it may be formed from interlocking segments or as a single monolithic structure.

Installation at site is then either completed by a float-out, tug assisted and sinking by a controlled ballasting method or by transporting individual segments by barge and then crane lifting them into position.

The gravity base 4 of the installation uses self-weight to set its foundation and several high pressure seawater jets 6, within the ring to improve penetration by soil liquefaction. These may be operated selectively to assist in levelling via a valved manifold.

The surface support vessel is equipped with industry standard high pressure seawater pumps on hire to supply the water jets 6, via a flexible hose 15. This is made up to a connection 16 on the main tower 1, during the installation. The action of the water jets 6, is controlled by computer software using positional feedback from sensors on the structure. These sensors measure the vertical alignment and depth of penetration of the gravity base 4 and hence the position of the tower 1. The majority of this equipment is removed on completion of the installation for return to hirer or for use on other projects. The steel tubes supplying the water jets 6 are an integral part of the reinforcement steelwork of the tower structure. The turbine 2 and its tunnel 3 is protected from ingestion of large current-carried debris at each entrance at either side of the structure. Two dome-shaped steel meshes 17 and 18, deflect large items and only allow pieces to pass through the turbine which are small enough not to cause damage.

Maintenance and damage repair may necessitate holding the turbine in a stalled condition for the duration of the work. A docking station 26 is provided to receive light watercraft enabling access to the tower for maintenance crew. Also, if divers are to enter the tunnel 3, the current flow must be entirely eliminated. A large valve will be installed as a permanent feature. Several valve concepts are available to achieve closure of the tunnel. These include but are not limited to ball, gate, butterfly, iris or louvre. The mechanism described below is the most sophisticated and reliable but is also the most costly of the available options. The final selection of valve type for any particular structure will be largely dependent on, and a trade-off between, the perceived damage risk and cost of repair for the selected operational site and the extra cost of a

superior valve mechanism. The two requirements for maintenance repair, i.e. turbine stall and zero current for diver access, are simultaneously achieved by the following equipments which are illustrated in figure 4. A ring frame 19, carries two shutter doors 20 and 21 which are shaped to conform to the domed meshes, 17 and 18. The ring is capable of being rotated on a set of rollers 25 about a vertical axis to position each of the doors. The diameter of this ring frame 19, exceeds the diameter of the main tower 1, in order to allow the shutter doors 20 and 21 to be positioned opposite the domed meshes 17 and 18. They are then retracted to make a seal by either mechanical or hydraulic equipment which is operated from the control centre 13. The concept of the above device may be compared to the operation of a ball valve, but with the casing revolving rather than the ball.

Industry standard mats 22, consist of concrete blocks linked together by polymer ropes as illustrated in figure 3, are placed by the surface support vessel around the base of the main tower 1, to prevent the current flow scouring away the seabed at the foundation keyring 5. A further enhancement of long-term stability is achieved by incorporating polymer filaments 23, into the concrete mats 22, which mimic the well-known aggregating properties of seaweed on current-transported small particulates. These strands reduce the velocity of the particles sufficiently to encourage deposition. The combined action of mat and filaments results in a beneficial build-up of material at the base of the structure in a relatively short time. This process is very important in ensuring the long term stability and integrity of the structure's foundation in a fast-flowing tidal stream. These mats are readily available items of commercial hardware to custom design.

Finally, a navigation warning to local shipping in transit is mounted on the top of the aero-generator mast 10 and is provided by a flashing illuminated beacon 24,

## CLAIMS

1. A marine power station driven by the combined energy of the wind and the tide to generate electricity.
2. A marine power station as claimed in claim 1 incorporates a subsea water turbine driving an electrical generator, operating in a circular cross-section tunnel and driven by the diurnal tidal current.
3. A marine power station as claimed in claim 2 incorporates a topsides horizontal axis wind-powered device driving an electrical generator and mounted on a tubular mast.
4. A marine power station as claimed in claim 2 incorporates a topsides vertical axis wind-powered device driving an electrical generator and mounted on a tubular mast.
5. A marine power station as claimed in claim 2 which is a single monolithic structure.
6. A marine power station as claimed in claim 2 which is assembled from individual elements on site to create a single structure.
7. A marine power station as claimed in claim 2 which has an automated integrated control, monitoring and distribution system for both power generation devices.
8. A marine power station as claimed in claim 2 which incorporates a self-acting gravity-driven foundation section with a shear keyring.
9. A marine power station as claimed in claim 8 which includes several water jetting nozzles disposed vertically and radially in the keyring of the foundation section of the structure.
10. A marine power station as claimed in claim 9 and all preceding claims which is connected to an onshore terminal by a buried subsea electrical cable having power and two-way multiplex signal elements.
11. A marine power station as claimed in claim 10 and all preceding claims which has debris meshes fixed to each end of the turbine tunnel.



12. A marine power station as claimed in claim 11 and all preceding claims which has a means of closing off the current flow through the turbine tunnel.
13. A marine power station as claimed in claim 12 and all preceding claims which has shutter doors fixed to a rotating ring frame which may be operated to close off each end of the turbine tunnel in order to exclude tidal current flow during downtime.
14. A marine power station as claimed in any preceding claim which has a docking station for light watercraft.
15. A marine power station as claimed in any preceding claim which operates automatically and autonomously and is normally unmanned except for maintenance and repair.
16. A marine power station as claimed in any preceding claim which is constructed from reinforced concrete or a steel fabrication or any combination of these materials.
17. A marine power station substantially as described herein with reference to figures 1-4 of the accompanying drawings.



INVESTOR IN PEOPLE

Application No: GB 9912872.0  
Claims searched: 1-17

Examiner: J. C. Barnes-Paddock  
Date of search: 16 October 2000

## Patents Act 1977 Search Report under Section 17

### Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:  
UK Cl (Ed.R): F1S (S28A) F1Q ( QBB QBC QCX QDC QDD) F1T  
Int Cl (Ed.7): F03B 3/00, 04, 06, 08, 13/10, 12, 22, 26 ; F03D 1/00, 02, 3/00, 11/00, 04  
Other: Online: WPI EPODOC PAJ

### Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
XP	GB2348465 A	(IT) See Figure 4. Mast mounted combined air and water generator.	1, 14-16
X	GB2307722 A	(HUNTER) See Figure 4. Buoy mounted vertical axis wind and water turbines.	1,15
X	GB2279412 A	(WHEELER) See Figures 1, 3. Offshore rig with horizontal axis wind and vertical axis enclosed water turbines.	1-3 11,14 16
X	GB2039624 A	(APPLEGATE) See Figure Floating power station with tidal turbine in tunnel and axial wind turbine.	1-3 12,15,16
X	JP030189372	(HITACHI) See Figure 1 and PAJ abstract. Vertical axis wind 2 and ducted tidal water 22 turbines.	1,2,4,15 16
X	JP110044288	(OOTA) See the Figure and WPI abstract accession No: 1999-199722 [17]. Arrangement of horizontal water and vertical axis wind turbines	1,15,16

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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